



MULTI-NATIONAL AROUND THE CLOCK COLLABORATIVE SENIOR DESIGN PROJECT

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This paper describes a multi-national design experience involving students from the Technische Universität München, the Technische Universität Darmstadt and Clemson University. These students worked collaboratively on their senior design project across boundaries of time, countries, and even continents. They had to overcome the educational background differences, the language barriers, the location distribution, and the time zone issue. In spite or rather because of these difficulties, the students learned tremendously, and taught us much. The undergraduate/graduate teams exceeded expectations in delivering a design to BMW, the client company. Some of the lessons learned are expanded upon in this paper.

PEDAGOGICAL MOTIVATION

The design experience is an integral part of most mechanical engineering curricula in the US and overseas. The German design methodology has been closely followed and used in American Universities as evidenced by the programs that have adopted textbooks such as Pahl and Beitz [Pahl and Beitz, 1996]. For over 30 years, Clemson University has had a very successful senior design experience for mechanical engineering students. Ten years ago, multi-disciplinary design teaming was initiated bringing students from mechanical, industrial, chemical and electrical together. Eight years ago, the design experiences were expanded by involving multiple universities (USC, GaTech). This experience has been widely described in the literature [a,b,c,d] [Dixon, 1997], and recent collaborative design experiences with other departments and Universities continue to illustrate everyone's eagerness to prepare the students for the challenges they will face when leaving the University. These projects continue to be an integral part of the capstone design experience of the students. As part of the evolving needs of industry, the senior design experience is now expanding to include multiple countries. Last year, contacts were established between Universities in Germany and Clemson to consider how to establish multi-national design experiences since the economy is transitioning from a national model to a global one. A pilot project was completed in the Spring semester 2000. This paper describes the "24-hour Around the World Around the Clock" project funded by BMW and involving the Technische Universität Muenchen, the Technische Universität Darmstadt in Germany and Clemson University in South Carolina. Our aims are to enrich the design experience of our graduates, and team up senior students with graduate students to better mold the design process to the needs of the changing world.

ECONOMICAL MOTIVATION

Time to market is a big issue for any manufacturing company in today's highly competitive market. Another driver is the globalization of the market, and the emergence of global companies with expertise distributed all over the world. An attempt to accelerate the design process may be achieved by increasing the time designers spend on a project in a 24 hour period. With engineers distributed all over the world, and using their expertise during their respective working hours, the concept of a 24hr design process may be realizable.

METHODOLOGY

The first aim of the project was to develop the methodology to perform 24 hours – around the clock - distributed collaborative design. Next, we used that methodology to solve the typical problems in global collaboration.

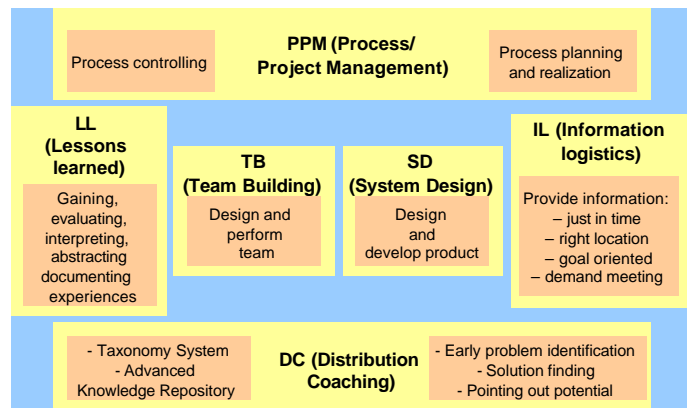


Figure 1: Distribution Methodology

The Distribution Methodology is the basis for solving complex and multidisciplinary problems in global engineering design. The methodology offers various tools and methods and consists of six interrelated elements



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(figure 1): Project and Process Management, Team Building, System Design, Distribution Coaching, Information Logistics and Lessons Learned.

MECHANICS

The task of the project was to design a variable speed, mass balanced, easy to assemble one-cylinder test-bed engine for a car manufacturer. Every team worked on the design task and passed the baton to the next team in a different location (time zone). Two scenarios on how to distribute the work were tested and analyzed. (Figure 2) The first consisted in having each sub-team (location based) work on the complete problem. Once solutions were generated and the decision on the “best ones” done, the students worked in a concurrent design mode, with individuals at each location responsible for a discipline or task. Social (teaming issues, language barriers, educational backgrounds) and technical problems (data transfer, data sharing, design process, units, CAD issues) were recorded and resolved through the help of the design team and special design coaches. The three teams located in Clemson, Darmstadt and Munich consisted of 3 students and a “coach” each, in addition to Faculty and additional staff at the various locations.

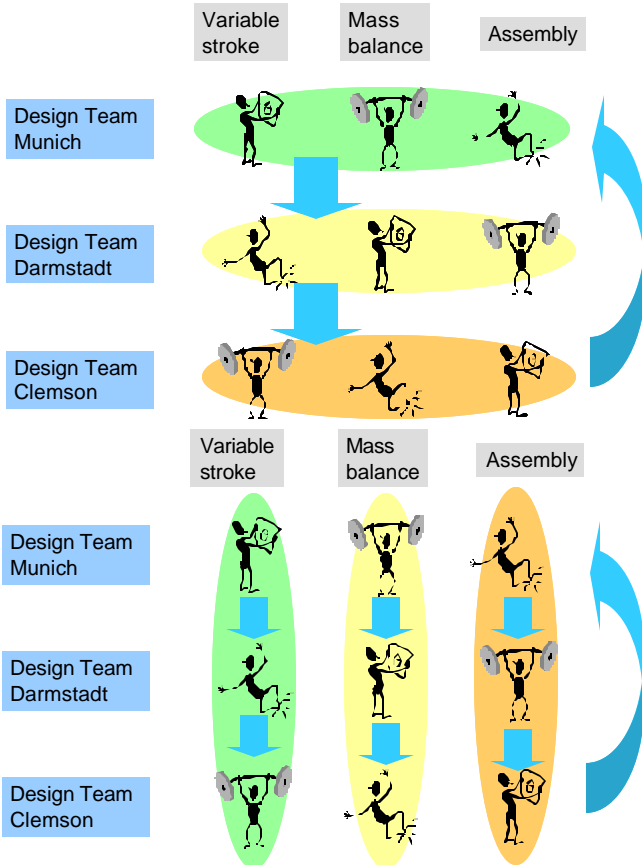


Figure 2. Distribution Scenarios

PREPARATION

The project was initiated and carefully orchestrated by Mr. Heiko Gierhardt, a Ph.D. candidate at the Technical University of Munich. Significant preparation and coordination between the sites was needed to formulate the

problem, define the bounds of the project, its expectations and deliverables. A student from the Technical University of Munich performed the design requirements phase in Germany and then joined Clemson. He participated in classes while helping another Munich student test collaborative software tools. The student teams (seniors at each university) were selected, and a kick off meeting in Germany allowed the students to meet with each other and with the client, to discuss the project, its expectations, and to formally establish the design teams. Upon returning home, the design project was initiated.

DESIGN METHOD AND TEAMING

The Pahl and Beitz design process (Pahl and Beitz, 1996) was used as the underlying methodology agreed upon for all the members to follow. Initial attempts not to define a methodology resulted in each team doing what it likes most, and the coaches intervened to put the project on track. The methodology was complemented by various techniques such as the “Distributed Creation Method” that allowed students to find and document solutions, and decomposition and criteria selection methods (Figure 3) that were adapted to the particular conditions as the design progressed. Several design gateways were instated to monitor the progress of the teams. They allowed the teams to present their work using web based technology and video conferencing to the client and to the instructors. The teaming issues were monitored by the coaches, the faculty and a social sciences scientist, and various interventions helped the members understand where they were in the team formation stage and how to resolve problems. One significant observation was the need to break away from the localized team paradigm and instate a global team spirit. The dynamics of multi-national collaborative teams were significantly different from the ones we observed in the past. One main issue for the success in global teaming was the continuous support of the team building process. The sequential and concurrent design processes used forced the students to commit to the design task, to spend a significant number of hours each day working on the project in order not to lag behind and appear less prepared.

Variable Stroke	Weight										Solution NO.1				Solution NO.2					
	C		M		D		1-3 Avg		1-10 Avg		C	M	D	Aver	C	M	D	Aver		
	1-3	1-10	1-3	1-10	1-3	1-10	1-3	1-10	1-3	1-10										
Stroke Range (54-110mm)	2	6	2	7	3	10	233	757	3	8	4	5	3	8	6	5.667	5	5	5	5.000
How continuous is variable stroke?	1	4	2	6	2	8	167	600	5	9	5	6.333	6	5	5	5.333	5	5	5	5.000
Display stroke change (within No.1/No.2?)	3	7	1	2	1	2	167	367	5	3	5	4.333	5	5	5	5.000	5	5	5	5.000
Maximum Torque 120 Nm - DEMAND	0	0	0	0	0	0	0.000	0.000	3	4	5	4.333	6	4	3	4.333	6	4	3	4.333
Friction	1	3	1	2	1	2	100	233	7	8	7	7.333	7	8	7	7.333	7	8	7	7.333
Stiffness of construction	3	10	3	10	3	10	300	1000	3	6	5	4.667	4	7	5	5.333	4	7	5	5.333
Support different con rod lengths	0	0	0	0	0	0	0.000	0.000	7	9	8	8.333	7	9	8	8.333	7	9	8	8.333

Design Criteria	Weights	Scores
Overall score (not weighted)	01.41	63
Overall Score (weighted 1-3)	113	62.77
Overall Score (weighted 1-10)	391	63.13
Rank (1-3)	18	18
Rank (1-10)	18	18

Figure 3. Selection Matrix



EXPECTATIONS

Our initial expectations were that the students will encounter major communication hurdles and would solve them, but that the design itself would suffer because of that. We did not expect the students to go too deeply into detail design, but that they would come to a consensus on a solution and give a general description. We were very pleased to see that the students were able to really deal with the communication bottleneck, overcome it, use the communication channels to their advantage, and produce a detailed solution that can be directly taken to the production facility (Figures 4 and 5).

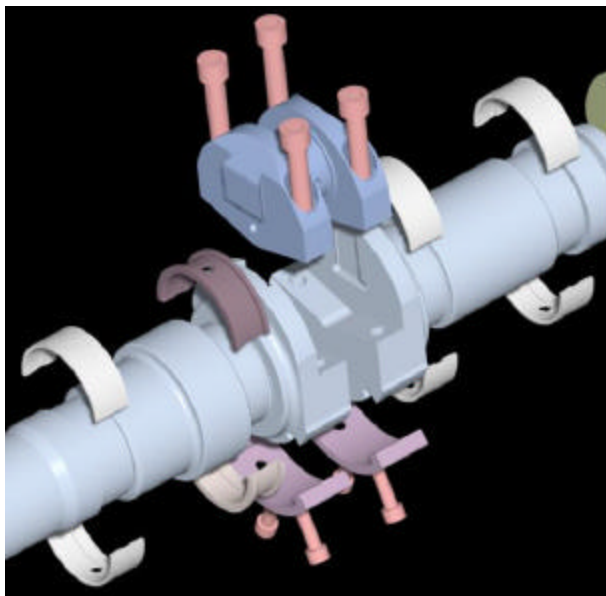


Figure 4. Example Solution in Pro-Engineer

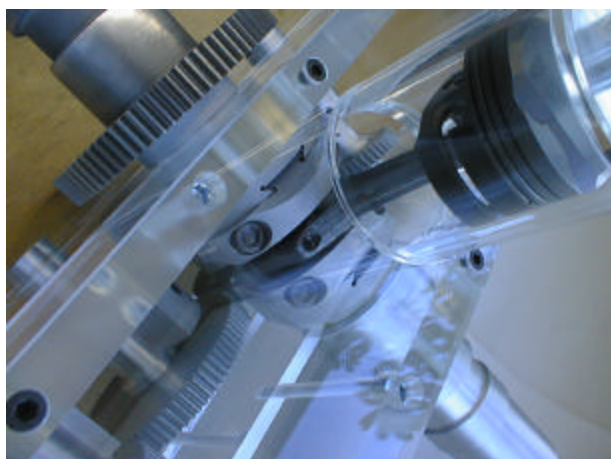


Figure 5. Prototype manufactured

TOOLS

The students relied on web based tools to do much of their communication tasks. NetMeeting [Microsoft, 2000] (Figure 6) was used as the communication platform, occasionally supplemented by Intel ProShare [Intel, 2000] to give common presentations. The common database was

stored on a Hyperwave [Hyperwave, 2000] server named KIC (Knowledge Information Center). Throughout the conceptual design phase, these tools seemed sufficient, but when the detail design phase started, the limitations of not having a common product data management environment made the sharing task difficult. The students used Pro-Engineer to do their drawings, and would send the files over to the next site. An exchange and a solution form were devised and used color coding and defined fields. The forms enabled sub-teams to draw ideas, write some comments, and solicit input from others. A sample solution form is illustrated in figure 7.

PRESENTATION

Upon completion of the design task, the students submitted their design project orally (using video-conferencing) and in writing and discussed international collaboration issues. The coaches produced a separate document describing the process, the need for intervention and the lessons learned. Papers were [Lindemann et al., 2000] [Lindemann et al., 2000] and are in the process of being written on the subject and a patent application is under consideration on the design the students generated.

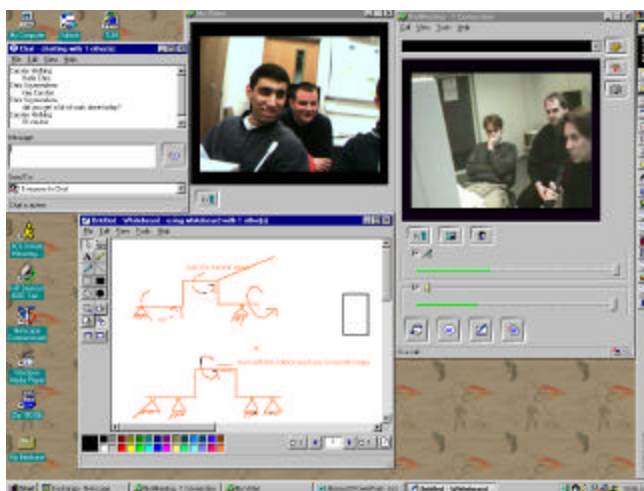


Figure 6. NetMeeting environment

<p>Critical / Info needed:</p> <ul style="list-style-type: none"> • <i>irregularity of movement - how important is this? It will change the thermodynamic process</i> • <i>crankradius not const.</i> • <i>Useful to use different gear forms (not round) to generate variable stroke range during one stroke -> go on with variations</i> • <i>stress/wear in the gears?</i> • <i>Are the gears really necessary or could the pin handle the stresses</i> 	<p style="color: red; font-size: small;"><i>What is about not using a gear, just a wheel to prevent the irregular movement</i></p> <div style="text-align: right; font-size: small;">Derived from file: done</div>
<p>Brief description:</p>	<p>Name of the solution: gearmaster</p> <p>Drawing No: 3.1</p> <p>Creator: Team Munich</p> <p>Date: 01/24/00</p>

Figure 7. Sample Solution form



CONCLUSION

The Around the world Around the Clock design involving three universities was extremely successful. Much was learned from this exercise, and we are currently in discussion with international companies to continue this design experience. A workshop will be offered in December 2000 to global companies. The aim is to transfer lessons learned and to solicit projects for future students. This will enable us to provide to some of our senior students an enriching international experience in their senior design project and continue adapting our curriculum to the needs of the changing economy.

CONTRIBUTORS

Contributors to the work are:

Mr. Heiko Gierhardt, Project Leader (TU Munich)
Mr. Hans Dieter Gaul, (TU Munich)
Mr. Daniel Fuchs, (TU Munich)
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Ms. Christiane Baumann (University of Munich)
Mr. Thomas Ott (TU Darmstadt)
Dr. Joel Greenstein (Clemson University)
Mr. Jonathan Maier (Clemson University)
our industrial partner and all the students involved.

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 - (ii) National Safety Council Meeting, Chicago, IL, September 17, 18, 1996.
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